Architecture for Cognitive Networking within NASA's Future Space Communications Infrastructure
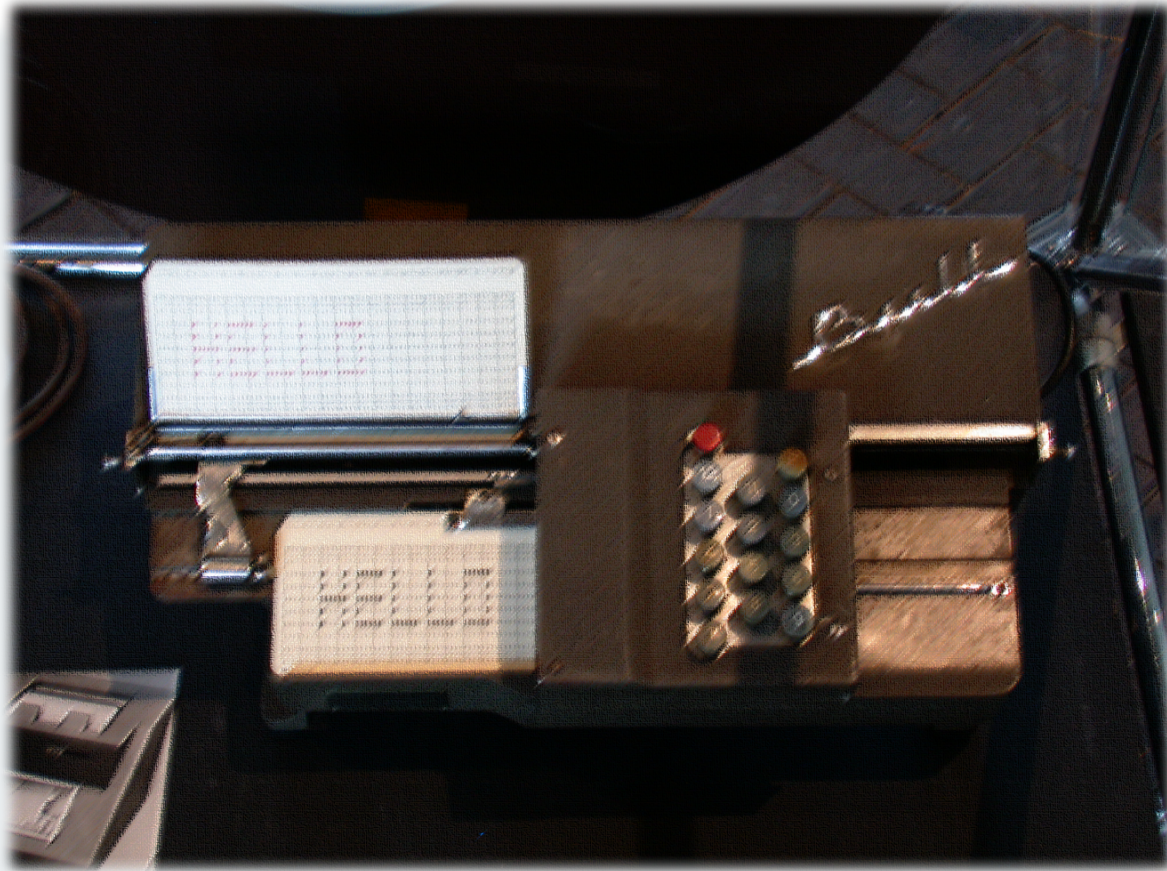
Presented By: Gilbert Clark / MTI Systems

Authors

Gilbert Clark and Wesley M. Eddy/MTI Systems

Sandra K. Johnson/NASA Glenn Research Center

James Barnes/MTI Systems
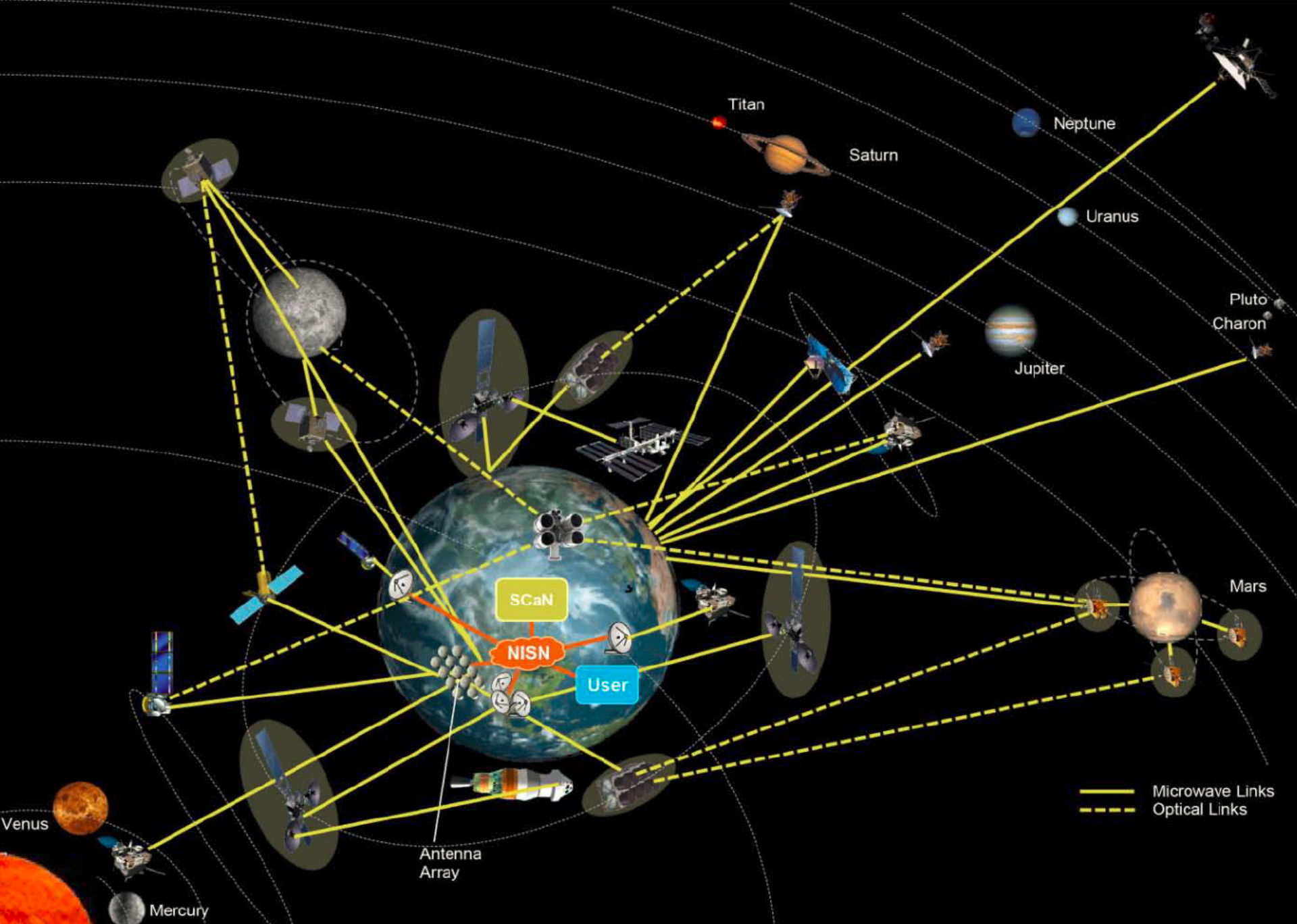
David Brooks/VPL

Presenter Biography

Agenda

- Discuss cognitive and possible roles in future SCaN

- Discuss architecture concepts
    - What might cognitive look like?
    - Definitely more than just the radios!

- Describe Cognitive Agent prototype software
    - Cognitive networking framework on the SCaN Testbed

- What does future work look like?

SCaN Future Architecture

- Moving away from discrete networks
  - Space Network, Near Earth Network, Deep Space Network, …

- Moving toward unified architecture
  - Seamless service provision, service interfaces, and scheduling for *all* network elements
  - Cross-layer services: raw signals, bitstreams, link-layer frames, packets, UDP, delay-tolerant networking, …

- Future solar system internet (SSI) as described by CCSDS
  - International, government, and commercial users
    - Should all use networks *responsibly* …

- Goals for cognitive
  - Reduce user burden
  - Mitigate operational risks due to growing complexity
  - Open-loop communication and navigation services
    - Reduce *need* for direct operator intervention

Titan

Neptune

Saturn

Uranus

Pluto
Charon

Jupiter

Mars

SCaN

NISN

User

Venus

Antenna
Array

Mercury

Microwave Links
Optical Links

SCaN

NISN

X-00003-00

Goals: NASA Intelligent Routing (NITRO) Effort

1 Reduce operator burden
Enhance performance on operational efficiency metrics …

2 Improve operator efficiency
Support scale-up in complexity, diversity, and volume / capacity …
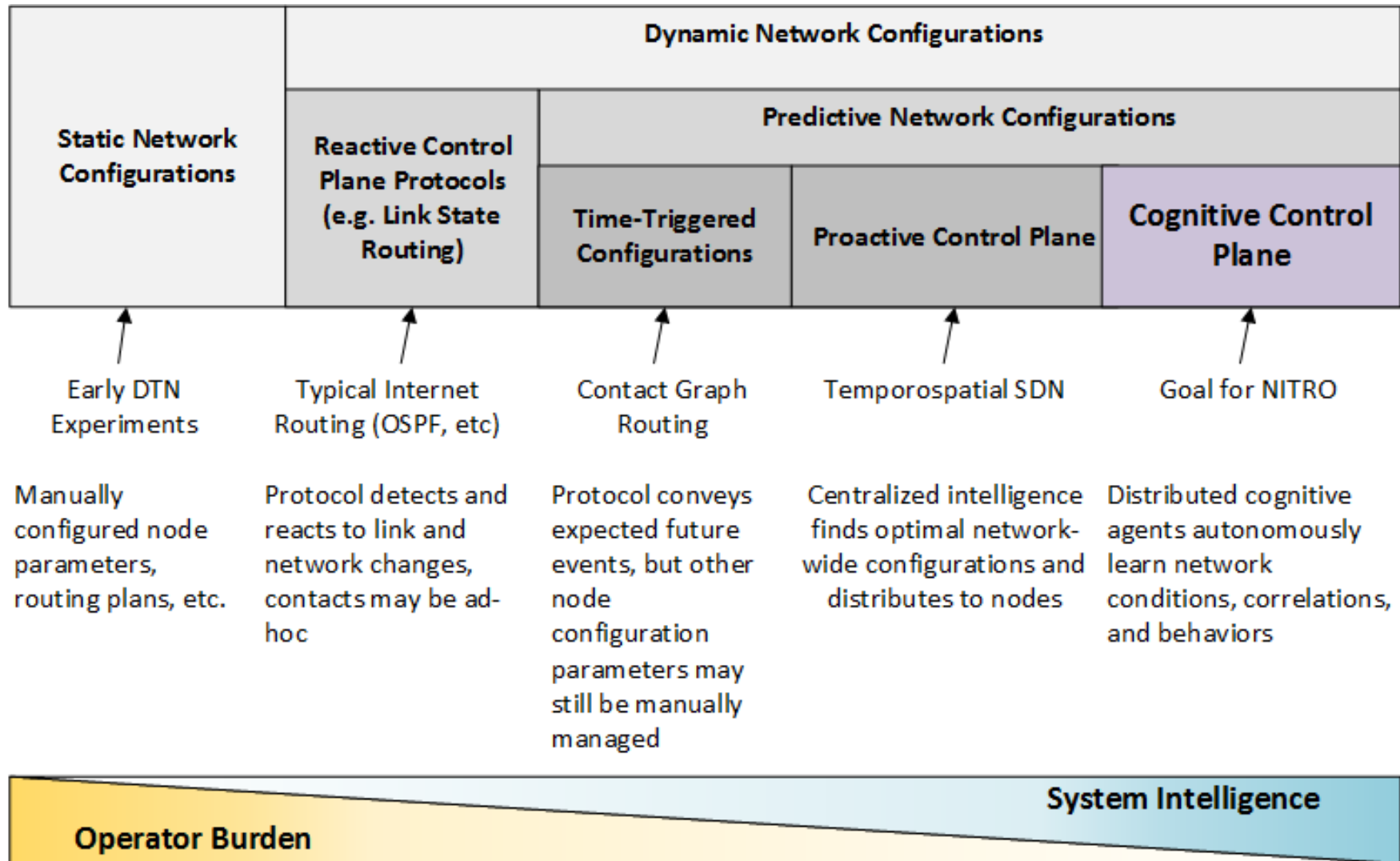*… without a corresponding scale-up in human resource allocations*

3 Facilitate autonomous operations
Enable operations where no human can support communications infrastructure (e.g. Mars)

Iterative Development

Static Network Configurations	Dynamic Network Configurations			
	Reactive Control Plane Protocols (e.g. Link State Routing)	Predictive Network Configurations		
		Time-Triggered Configurations	Proactive Control Plane	Cognitive Control Plane

Early DTN Experiments

Manually configured node parameters, routing plans, etc.

Typical Internet Routing (OSPF, etc)

Protocol detects and reacts to link and network changes, contacts may be ad-hoc

Contact Graph Routing

Protocol conveys expected future events, but other node configuration parameters may still be manually managed

Temporospatial SDN

Centralized intelligence finds optimal network-wide configurations and distributes to nodes

Goal for NITRO

Distributed cognitive agents autonomously learn network conditions, correlations, and behaviors

**Operator Burden** → **System Intelligence**

Toward Cognitive System Engineering

- Not really One True Cognitive to rule them all
  - Instead, things are situationally appropriate
    - Huge number of different AI and ML techniques
      - Neural networks, genetic programming, SVM, and more!
    - Different techniques make sense in different situations
    - Need to blend autonomy and automation …
      - … in ways that make sense *for the mission*
  - Many different techniques to achieve cognitive behaviors ...
    - Cognitive offload – perform computation elsewhere
    - Autonomic computing / networking – "self-management"
    - Information-centric networking – emphasize "what", not "where"
  - … optimized across many different "domains"
    - "big brain vs. little brain"

Cognitive Scope
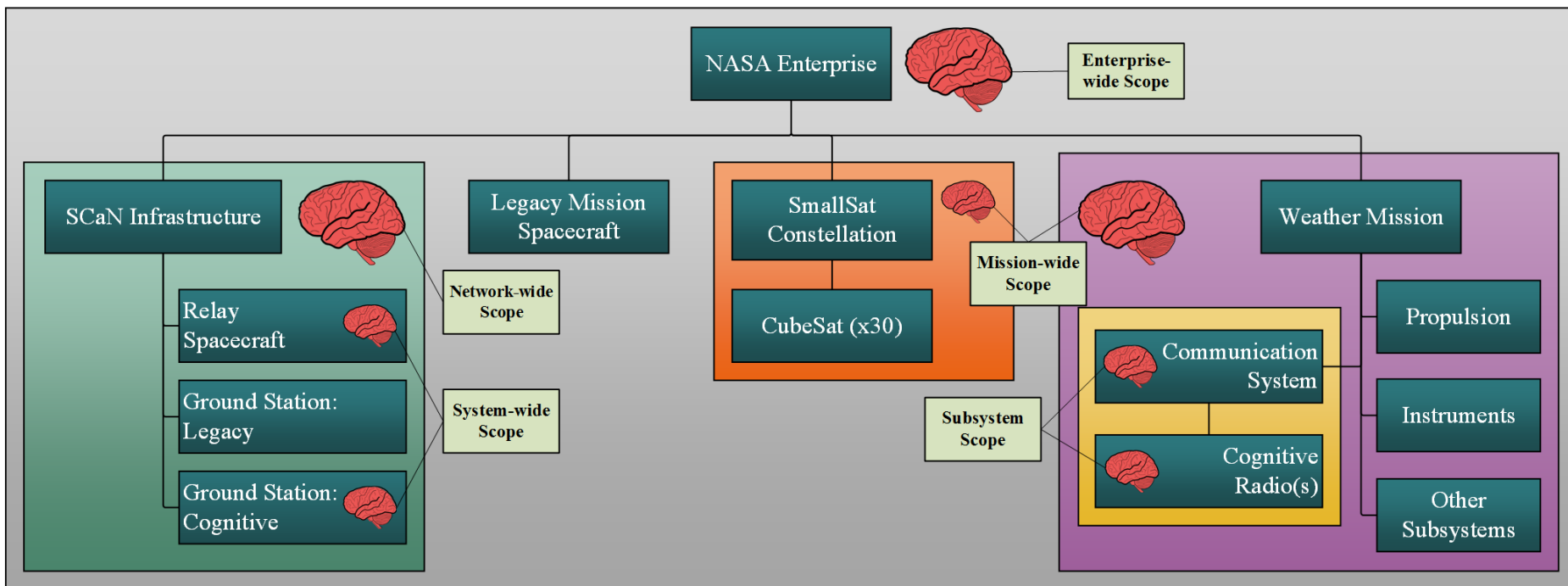
Prototype Cognitive Agent

- ## Prototyping intelligent routing software and protocol
  - Built to support present and future flight / ground systems
    - Current on-orbit testing via SCaN Testbed ...

- ## Empirically determines link characteristics …
  - … and makes routing decisions based on goals
    - "minimize latency", "maximize reliability", etc.

- ## Also collects data that can be used for future work …
  - In order to learn, we need data from which to learn …

- ## … and offers a way to swap cognitive engines
  - Less of a focus on immediate intelligence in *this* agent
  - More of a focus on a good API and an extensible framework
    - Make future experiments easier …

Cogent – Construction
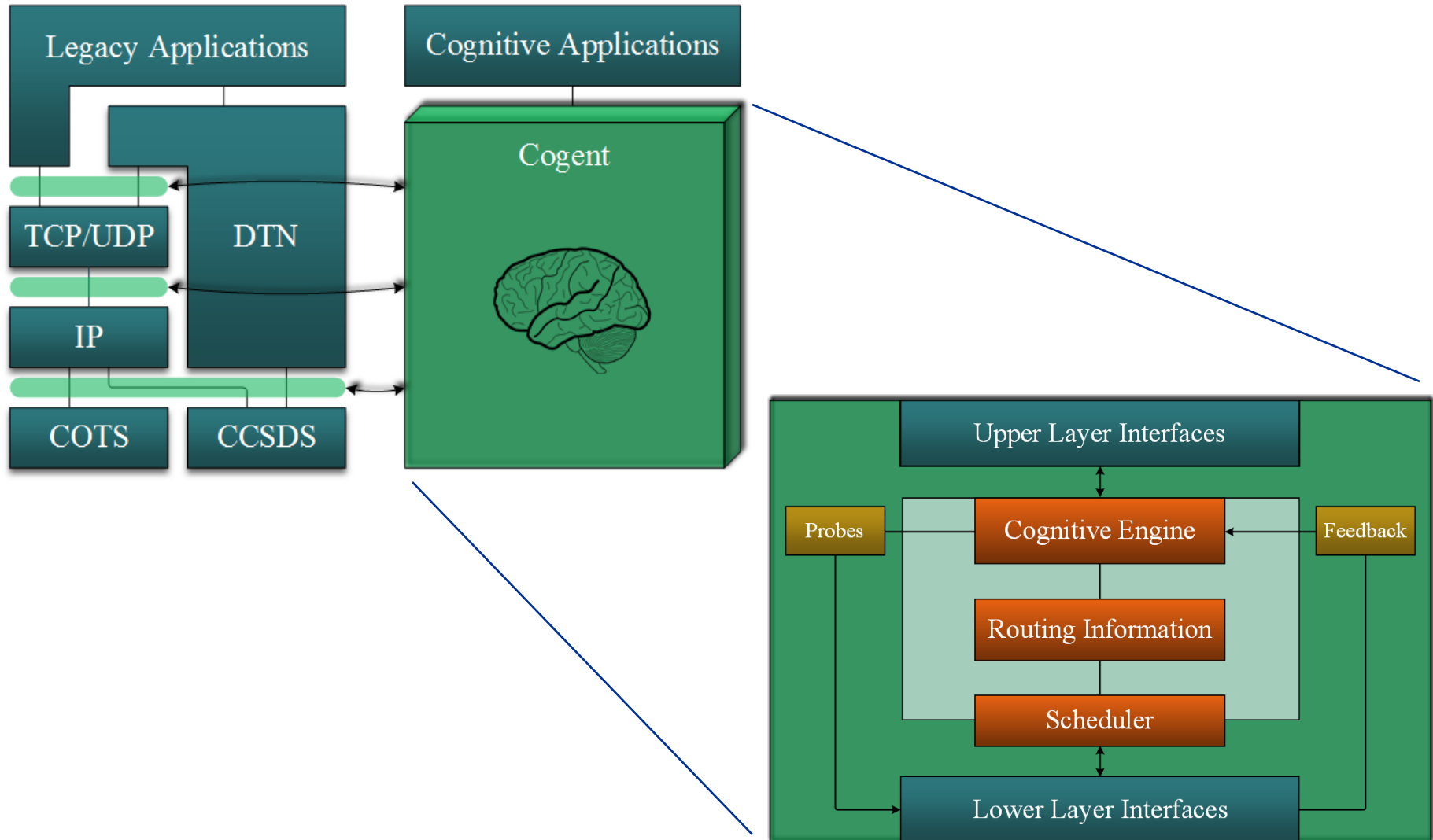
Technology Gaps and Future Work

- ## Cross-layer signaling
  - Standardization is an important aspect of this …

- ## Algorithm development
  - More intelligent approaches to autonomy and management

- ## Computational offload
  - Incremental upgrade of static hardware resources

- ## Debugging / management of intelligent systems
  - "You did *WHAT*?! What were you *THINKING*?!"

- ## Self-knowledge
  - "Generally, I'm not very good at …"

- ## Self-design
  - "Wouldn't it be nice if I could fly?"

Wrapping Things Up

- Thanks for listening!

- Speaker: Gilbert Clark – gilbert.j.clark@nasa.gov
  - Feel free to contact with questions, concerns, etc.

- Questions? Comments? Concerns? Criticisms?